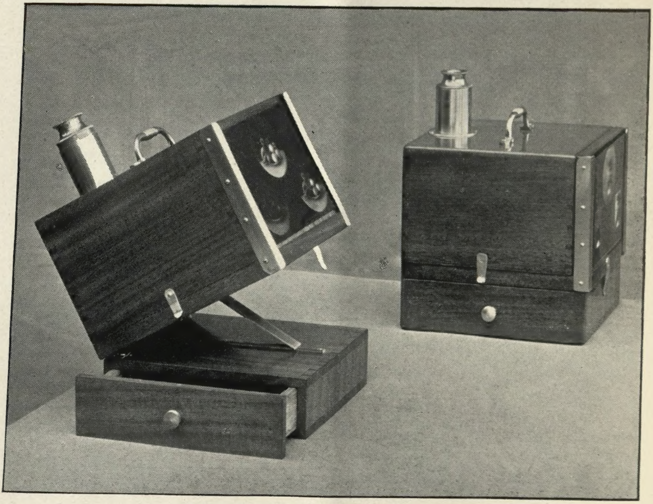

THE PHOTOCHROMOSCOPE.

THE CHROMOGRAM.

HAND-BOOK

TO THE

PHOTOCHROMOSCOPE

BY ITS INVENTOR

FREDERIC E. IVES

WITH CHAPTERS ON

THE NATURE OF LIGHT, AND THEORY OF COLOR

BY SOME OF THE FIRST AUTHORITIES

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INTRODUCTION.

IT is little more than half a century since Daguerre first fixed the camera image on the silver plate which, under the name of the Daguerreotype, astonished and interested the world.

The success of this great discovery was followed by a universal expression of desire for a method of photography in the natural colors. Time after time it has been asserted that the problem was solved, but one disappointment followed another until, as a German writer recently said "photography in the natural colors seemed, only a short time ago, as far away as the stars in the skies."

Nevertheless, the efforts to solve the problem have not been all in vain; for if we have not exactly such color-photographs as the world has been looking for, we have certainly accomplished the reproduction of the colors of nature by at least one strictly scientific method, which is simple and reliable enough to be practically available.

The problem has been attacked from several different directions, the most important of which

are (1) the production of pigment colors on a light-sensitive plate by the direct action of light, (2) the production of so-called interference colors by the action of light reflected back upon itself within the sensitive film, and (3) the production of composite color photographs, an idea which has culminated in the Photochromoscope system.

The first method has never yielded colors that were either permanent or true to nature.

The second method, which originated with Prof. Lippmann, of Paris, has produced, out of thousands of plates exposed in the course of the year 1893, about a dozen pleasing, but by no means perfect, color photographs of objects. These can only be seen directly by light reflected from the film deposit at the critical angle; or in projections on the screen up to two or three feet in diameter, by the aid of a powerful electric arc light.

The third method requires the production of three or more negative images to make a color record, and synthesis by means of an equal number of positive images, combined by superposition, to reproduce the colors. This is a more complicated procedure than either of the others, but it has a greater variety of applications, and as carried out in the Photochromoscope system, it yields almost ideally perfect results, and under suitable conditions is as simple and easy

to practice as ordinary photography. This cannot be said of any other method that has produced even promising results.

Composite Heliochromy was originally suggested in 1865, as a means of producing colored pictures upon paper. The first attempt to carry it out was made in 1869, by Ducos DuHauron, who, with Charles Cros, considerably modified the original plan, and also conceived the idea of synthesis by screen projection and by special optical devices; but, owing to false and misleading theory, and the inadequacy of the devices employed, none of these attempts were successful, either as to quality of results or practicability of procedure.

The attention of the author was directed to the subject as long back as 1878, but although much work was done, within the following years, very little real progress could be reported until 1888, when success was reached with the method as to quality of results in all of its applications. This was accomplished by perfecting the theory and practice of the negative-making process, so as to obtain the first true color-records, by optical synthesis with colors representing the three fundamental color sensations, and by a system of clear gelatine printing and subsequent dyeing by immersion, for obtaining prints for synthesis by superposition. A method of reproduction by the type

printing press was also devised (1881) employing a single line process block for each color, but this yielded comparatively crude results.

These improvements were followed by the invention of the Photochromoscope camera, in which the color-record is produced by a single exposure, on a single sensitive plate, and the Photochromoscope itself, by which the synthesis is obtained without the trouble of making either color prints or screen projections.

Details of the history, principles and practice of the process were given in papers read by the author before the Society of Arts, in London, and published in the Society's Journal, May 27, 1892, and May 19, 1893.

It is not intended in this little handbook to deal with anything but the Photochromoscope, which, far better than either of the other developments of composite heliochromy, is calculated to bring home to everybody the practical realization of color photography.

Besides the more obvious uses of the Photochromoscope, it promises to serve important artistic, industrial and educational purposes. It will enable the artist to study in his own studio, and at his leisure, the technique of the old masters, whose works may be otherwise quite inaccessible to him, and to keep ever present with him for comparison or submission to

patrons the paintings that have left his hand. It will enable the manufacturers of choice carpets or tapestries, the dealers in rare oriental rugs, the manufacturers of stained glass windows, house decorators and others, to show and compare with ease and facility the coloring of the finest productions of the artist or artisan. It will enable the physician and surgeon to study the appearance and progress of skin and other diseases through the photographic records of rare or typical cases. And by no means the least important of its applications will be its use in schools and colleges as a means of demonstrating the theory of color-vision in a manner at once entertaining and convincing.

THE PHOTOCHROMOSCOPE.

THE Photochromoscope is an optical device in which a special triple photograph, which is called a Chromogram, reproduces the light and shade and colors of Nature as readily as the phonograph and its wax cylinder, or phonogram, reproduces sounds.

The phonogram is a mechanical record of sound, and similarly the Chromogram is a photographic record of light and color. The phonograph translates the mechanical sound-record into sound, and the Photochromoscope translates the photographic color-record into color.

The Chromogram is a positive photograph, on glass, made in the usual way from a negative taken with a special camera, but otherwise in appearance just like an ordinary glass positive, except that there are three images of the subject on its surface instead of one. In the production of these three images, light, acting through selective color-screens, registers the colors of the objects, by making the lights and shades of the three pictures represent the relative effect upon the three fundamental color-sensations of the eye, according to the modern theory of color-vision. In the Photochromoscope, each image of the Chromogram

is seen by means of those rays of light only which excite exclusively the particular fundamental sensation which it represents; but by a system of mirrors the three images are superposed, and seen by the eye as blended into one, which no longer bears any resemblance to a photograph, but has the appearance of the object itself, as if viewed through a lens.

The Photochromoscope consists essentially of a box, open at both ends, with three colored glasses or screens (red, green and blue-violet), and three pairs of small mirrors, arranged within it. With such a simple device it is possible to view the monochromatic triple image of the Chromogram as a single image reproducing all the colors of the object photographed; but in order to magnify the image, to improve the illumination, and in other respects to add to the efficiency and convenience of the instrument, it is constructed upon a more elaborate plan, with condensing lenses, color-screens, mirrors, objective lens, focussing eyepiece, etc. A drawer is also provided as a convenient and safe receptacle for a number of Chromograms.

The arrangement of the parts is shown in Fig. 1. When the Chromogram slides into place under the brass guides at the front of the box, the three condensing lenses, G, B, R, correspond in position with the three images. Light from the positive of the green sensation, passing through the lens G, passes also

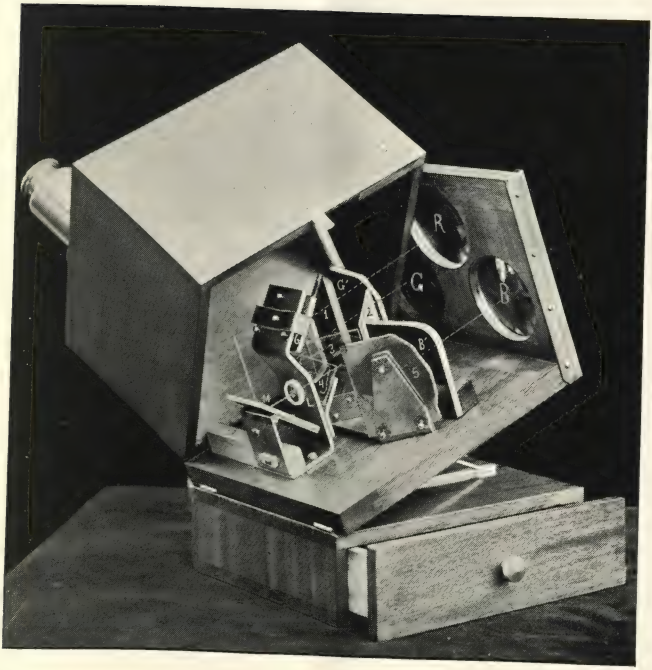

Fig. I.

through a green color-screen G1, to the silver mirror 1, then sideways to the silver mirror 2, forwards through the transparent mirrors 3 and 4, through the objective lens L, to the inclined mirror M, and upwards to the eye-piece ; under which it forms a green image.

Light from the positive of the blue-violet sensation, passing through the lens B, passes also through a blue-violet color-screen B1, to the silver mirror 5, then sideways to the transparent mirror 3, forwards (except a portion which passes through mirror 3 and is lost), through the transparent mirror 4, and the objective lens L, to the inclined mirror M, and upwards to the eye-piece ; under which it forms a blue-violet image, exactly coincident with the green image.

Light from the positive of the red sensation, passing through the lens R, passes also through a red color-screen, to the silver mirror 6, downwards to the transparent mirror 4, forwards (except a portion which passes through mirror 4 and is lost), through the objective lens L to the inclined mirror M, and upwards to the eye-piece, under which it forms a red image, exactly coincident with the green and blue images.

The red color-screen, for convenience, is fitted in the top of the box, and therefore does not show in the illustration.

INSTRUCTIONS FOR USING THE PHOTOCHROMOSCOPE.

THE best source of light for the Photochromoscope is a sufficient expanse of even white or grey sky, towards which the large lenses in front of the instrument should be directed, through a clear or open window, at such an angle as will show a well and evenly illuminated white disk when viewed through the eye-piece. The light, passing through the three large lenses and color-screens, at the proper angle, will produce the single white disk. *If the disk be not white, the Chromograms will not show the true colors of the objects.*

If the instrument be placed quite near to the window, the blind may with advantage be drawn down as far as will not affect the color of the white disk.

The outside lenses must be carefully dusted with the brush which will be found in the drawer. If there is any film or moisture on them, they may be wiped carefully with a soft linen handkerchief.

The Chromograms slide into place under the brass guides, with the labelled side in, and the projecting ends at the bottom. If put in wrong side out, the images may become scratched, the picture will be

out of register, and the colors wrong. Dust or finger marks on the Chromograms would show as spots of color and, must be removed. The picture side of the Chromogram will not bear rubbing without injury, but the glass side may be cleaned like the lenses.

The eye-piece should be focussed to give a sharp image by pushing it up or down in the tube. The image will be found perfect when the eye is kept steadily in the centre of the eye-piece, close enough to see all the picture at once.

When the instrument is in use, a cardboard shield, which is provided for the purpose, should be placed upright on the box, leaning against the handle, to shade the eye from the light of the window; when it is not in use, the shield will serve to protect the large lenses from finger marks or injury.

A *blue* sky is not a good source of light for the Photochromoscope, because predominant blue in the picture interferes with the true rendering of the colors. If the sky be a very light blue, and a part be selected which is near the horizon, and not too far away from the position of the sun, the effect will be better. When the sky is a bright blue, and direct sunlight is available, the opal glass (supplied with the instrument) should be placed over the brass guides of the Photochromoscope, and the direct rays of the sun, coming through an open window, should be allowed to

fall upon it. There is no better source of light than this; but in order to make it altogether satisfactory, the sun's rays must be carefully screened from the eyes, and the table upon which the instrument stands must be covered with a dark cloth, to prevent reflection.

If the above mentioned conditions are secured, the Chromograms will reproduce accurately the colors of the object photographed. Should the image appear at all misty, notwithstanding careful cleaning of the lenses, it may indicate that the inside lenses or mirrors require cleaning.* If the three images of the Chromogram are not perfectly superposed, so as to appear as a single sharp image, the mirrors may be out of adjustment, in which case the instrument must be readjusted by an expert. But this should never occur, if the instrument is handled with reasonable care.

The best artificial source of illumination for the Photochromoscope is an electric arc light, the direct rays of which must be allowed to fall upon the opal glass, just as when sunlight is used, but from a distance of only ten or fifteen inches. Under no circumstances should the direct rays of the arc light be allowed to reach the eye, or to fall upon any light colored object near the instrument.

A very effective illumination for the evening is

* See end of this chapter.

conveniently obtained by having an ordinary double convex hand-glass placed over the front of the Photochromoscope, resting upon the projections arranged to carry it, and for the source of light, a "Welsbach" incandescent gas light, within a 4½ inch dense opal-glass globe, and supported at a height of twelve or fifteen inches above the table. In this case, a blue-tint glass (supplied with the instrument) may be placed over the eye-lens, to whiten the light, and the globe should be placed exactly 15 inches from the Chromogram, in a direct line. With a little practice, it becomes easy to adjust the inclination and direction of the instrument for the best effect. An illuminating apparatus of this nature, including lens and stand, all enclosed in a box, is sold separately.

In the course of time, the bright surfaces of the inside lenses and mirrors receive a filmy deposit from the air, and the image appears misty. It then become necessary to clean these surfaces, and this operation must be performed with great care, to avoid scratching or dulling the delicate varnish surface of the mirrors, or throwing the instrument out of adjustment. The best material for this purpose, is soft, dry chamois-leather, a small piece of which may be folded and attached to a stick in such a manner that it can be made to reach all the surfaces that need cleaning.

PHOTOCHROMOSCOPE THEORY AND PRACTICE.

THE first satisfactory Chromograms were made by a procedure which represents the application of the Young-Helmholtz Theory of color-vision, in accordance with Clerk-Maxwell's measurements.* These measurements were made on the assumption that the fundamental color sensations correspond to the spectrum red at Fraunhofer line C, the green at E, and the blue below G The photographic color-screens were tested by photographing the solar spectrum, and were adjusted to secure density-curves in the spectrum negatives corresponding to the graphic curves in Maxwell's diagrams, which are supposed to represent the relative power of different spectrum rays to excite the respective fundamental color sensations. Careful experiments by Capt. Abney and other physicists having demonstrated that the fundamental red is lower, and the fundamental blue (violet) higher in the spectrum, than the positions above named, the color-screens were modified accordingly, although in practice the degradation of color consequent upon accepting Clerk-Maxwell's position for the fundamental colors is very slight.

* U.S. Patent No. 432,530, July 22, 1890.

Still further investigations by Abney and others have proved conclusively that no part of the spectrum accurately represents the true fundamental green sensation to a person having normal color-vision, but only that degraded as if by admixture of white at F, or of red at E. Since, however, the green of the spectrum is the purest that we can produce, measurements based upon the assumption that it represents the fundamental sensation are the best and only available ones for our purpose.

According to some authorities, we should accept a point in the spectrum just below F, as our fundamental green, because it represents the true fundamental merely reduced with white, instead of modified by admixture of red, as at E. On the other hand, there can be no doubt that the spectrum at E excites the green sensation more exclusively than at F. Whichever standard we base our procedure upon, we must suffer a slight degradation of adjacent color in reproductions of the spectrum itself,—in the blue-green if we accept E as the fundamental green, and in and below green if we accept a point higher in the spectrum. The spectrum at E has been accepted as the best representation of the fundamental sensation for our purpose, because actual experiments proved that a slight degradation of color is more difficult to detect in the blue-green than elsewhere.

The process as it is carried out should therefore, if there were no defect in either the apparatus or the negative-making process, reproduce the visual impression of every color in nature, with no loss whatever of depth and purity, except in blue-green and its combinations, which must be slightly paled by admixture of white.

But in actual practice, the process has other defects, which are chiefly due to the fact that the photographic scale of gradation is shorter than the scale of gradation of light and shade in nature. Owing to this defect, which is inherent in all photographic processes, there is a tendency to exaggerate color contrasts in the shadows, and to weaken them in the high-lights. This defect, however, has been shown to correspond to certain inherent defects of color-vision, for which, through force of habit, unconscious allowance is made, except in extreme cases.

The Photochromoscope was at first made with screens of very pure color, in order to realize as nearly as possible every theoretical requirement. Many people imagined that the reproductions seen in these instruments were even more strongly colored than the objects themselves. Actual comparison always proved that this impression was due to an error of judgment, such as has led many people to declare that, owing to condensation, the image of a landscape on the

focussing screen of a camera, is more strongly colored than the landscape itself. Only by photographic errors, such as making over-dense positives from under-exposed negatives, is it possible to actually exaggerate color contrasts in the Photochromoscope, as contrasts of light and shade are frequently exaggerated in monochrome photography. Owing however, to the prevalence of the error of judgment mentioned, it has been found permissible to compromise by a slight reduction of the purity of the Photochromoscope color-screens, which makes the colors less aggressive, and improves the general illumination.

The small importance of such theoretical defects as have been described, is exemplified by the fact that when the instrument has been exhibited in public, showing reproductions of objects that were placed close by for comparison, people have been seen to place their hands in front of the objects in order to convince themselves that they were not looking at a reflection instead of a reproduction.

Although the Photochromoscope furnishes a wonderful illusion of nature, the result must not be regarded as a mere "optical illusion." It is an optical illusion as to color only in the sense in which ordinary color vision is itself an optical illusion; for color is not objective, but a subjective sensation, and in ordinary vision exactly the same sensation may be produced

by quite different mixtures of spectrum rays. For instance, the eye cannot distinguish between the true yellow of the spectrum and a certain mixture of red and green rays, although the two kinds of yellow are just as distinct from each other, in a physical sense, as yellow and blue. The colors in the Photochromoscope image are just as real, just as definite in the manner of their production, and just as far from being a mere "optical illusion," as the colors seen by direct examination of the objects, because the action upon the eye and brain, in which the sense of color resides, are the same in both cases.

PART II.

PART II.

THE NATURE OF LIGHT,

By Professor Von Bezold.

THE most varied experiments and profound theoretical investigations, which again were proved and confirmed by experiments, step by step, compel us to form a conception of the nature of light, similar to that which we have already had for a long time of the nature of sound.

By these investigations it has been demonstrated that the sensation of light is produced by the vibrations of the so-called *ether*, a medium which fills the whole space of the universe, and penetrates all bodies. These vibrations are propagated with an exceedingly great velocity in space and in transparent bodies, and are thus the cause of the origin of the so-called wave-motions. A good representation of such wave-motions is given by the circles produced by a stone thrown into the water, or perhaps still better by the beautiful undulatory motion which may be observed when the wind sweeps over a field of ripening corn. In the one case the particles of water,

in the other the ears of corn, execute, one after the other, the same or a similar swinging movement; and this vibration is called wave-motion. But very different kinds of such wave-motion may be propagated simultaneously through the same medium, without essentially interfering with one another. If, for example, we throw two stones into the water at a short distance from each other, each of them will produce its circles, and we can without difficulty follow the course of the waves of these circles even in those places where they overlap one another.

The multitudinous systems of waves produced by the instruments of a full orchestra are propagated without impediment, not only through the air, but even through the narrow acoustic duct of the ear; and a practised ear is capable not only of following each part, but even the playing of each single instrument, in a brilliant symphony.

In reality, each individual particle of air naturally makes only one motion in any one moment of time; but this motion is qualified by all the separate motions which act upon such a particle, and by suitable apparatus these compound motions can again be resolved into their elements. We have such an apparatus for the waves of sound in the human ear, for the waves of light in the prism. The ear or the prism separate the waves of air or of ether, which

impinge on them, into waves, the vibrations of which take place in accordance with a simple law, and in a manner similar to the vibrations of the pendulum. Between such simple vibrations there cannot be more than two points of difference; they can differ, on the one hand, in the time which passes while one vibration is executed, and, on the other hand, in the distance which is travelled over by one of the particles in motion while making one vibration.

The time necessary for the completion of one vibration is called the period of vibration. Upon the length of this period depends, in acoustics, the pitch of the sound, in a musical sense; in optics, the hue of the color.

The length of path travelled over, or, what is the same, the greatest distance from the point of equilibrium reached by the particle during one vibration that is to say, the amplitude, determines, in the one case the intensity of the sound, in the other the brightness of the ray of light.

In the ray which emerges from the prism, the vibrations are executed according to the simple law just alluded to, and the differences between the variously colored rays arise only from the difference in the length of the period of vibration. But the duration of this period in the vibrations of light is exceedingly minute. The impression of red light

caused by one end of the spectrum is produced by vibrations of which 400 trillions are executed in one second, while as many as 790 trillions of vibrations correspond to the violet end of the spectrum. The numbers of the vibrations corresponding to all the other rays which lie between these two ends of the spectrum, will also be found to lie between the two numbers just mentioned.

THE ACT OF SEEING,

By Professor Von Bezold.

THE transparent media of the eye act upon the light which enters them, in a manner similar to the lenses of the camera employed by the photographer. They produce in the interior of the eye an image of the objects of the outer world. This image, under normal conditions, is projected upon an exceedingly delicate membrane, which is spread out in the inner part of the eye, and is called the retina. The retina is composed throughout of nervous elements, most cunningly constructed, each element being connected with the brain by fine nerve-fibres, which together form the so-called optic nerve. These elements are excited by light impinging on them.

The processes which a ray of light, or a bundle of such rays, is subjected to, in so far as they take place outside of the eye, are of a purely physical character. The passage of the rays through the transparent media of the eye is likewise regulated simply according to the laws of inanimate nature, and upon the retina of an eye freshly cut from a dead animal the image is produced as sharply and as clearly as upon that of a living eye.

The processes on the retina, on the contrary, are

of quite another kind. They are based upon the peculiar activity of the living organism, and their investigation, instead of being a part of the domain of physics, belongs to physiology. When two pigments are mixed upon the palette, the light emanating from them passes, before it reaches the eye, through a physical process, the laws of which are completely independent of the construction and of the activity of the sensitive organism. If, on the contrary, light of various colors falls simultaneously upon one of the elements of the retina, the different impressions must be blended into one upon the retina, and it is even possible that the blending does not take place until after these impressions have reached the brain.

In seeing, there are furthermore associated with these processes of a physical and a physiological nature the activities of the reasoning faculty and of the judgment. The image of the outer world is formed upon a child's retina quite as clearly as upon that of a grown person, and the sensitive elements are the same in both cases ; nevertheless, the child reaches out its hands after the sparrow upon the roof, or will even attempt to catch the moon. In the course of time however, the child, by means of the small differences between the images in the two eyes, which are caused by the difference in the position of each eye in relation to the objects existing outside of it, and by availing

itself of various other circumstances, acquires the faculty of judging of distances, and therefore immediately *sees* things in their proper position.

In the theory of color the investigator must deal at one time with purely physical facts, that is to say, with facts which are independent of the living organism ; then again with physiological processes, that is to say, processes which are entirely peculiar to this organism ; and finally there must be added to these the activity of the reasoning faculty, the judgment, and psychological and æsthetic questions.

THE THEORY OF COLOR,

By Professor Pickering

COLORS are sometimes divided by artists into primary, secondary, and tertiary; the first term being applied to the colors red, yellow and blue of the spectrum. The other colors of the spectrum are called secondary or binary, since, according to Brewster's theory, each is composed of two primary colors, while tertiary colors are formed by combining two secondaries. These terms are based on the erroneous theory that the three elementary color sensations are inherent in the light, and not in the eye. In reality, all the colors of the spectrum are equally primary, being composed of rays of uniform wave-length, and all ordinary colors are formed of rays from every portion of the spectrum, differing only in the proportions in which they are combined.

In considering the subject of color, or the sensation produced when waves of different lengths fall on the retina, we must recollect that this phenomenon is wholly subjective. Accordingly, our knowledge of the aspect of these waves depends wholly on the construction of the eye. Young, in 1802, was the first to show that all the phenomena of color could be

accounted for by supposing that the retina contained three kinds of nerves, each sensitive to waves of a certain length, that is, to a particular color. Other colors may be formed by exciting these nerves unequally. Thus a ray of yellow light will excite both the nerves sensitive to red and those sensitive to green, or will produce on the eye the same effect as if red and green rays are received together. In other words, red and green if mixed produce yellow, and not white as is commonly supposed. The theory of Young was, however, quite forgotten until again brought forward in 1853, when the experiments of Helmholtz and Maxwell added greatly to their probability, and showed that the three primary colors are red, green, and dark blue or violet.

The impression of color is wholly subjective or dependent upon the formation of the eye by which it is viewed. As far as the light itself is concerned, the waves of different colors are infinitely varied as regards their length, but, as the eye has only three tests for them by its three sets of nerves, our judgment is formed by the relative excitation of these three sets.

THE EFFECT PRODUCED UPON COLOR BY A CHANGE OF LUMINOSITY,

By Professor Rood.

IN our study thus far of colored surfaces it has been tacitly assumed that their action on the eye is a constant one, and that a red surface, for example, will always appear red to a healthy eye as long as it remains visible. In point of fact, however, this is not quite true, for it is found that colored surfaces undergo changes of tint when they are seen under a very bright or a very feeble illumination. Artists are well aware that scarlet cloth under bright sunshine approaches orange in its tint; that green becomes more yellowish; and that, in general, a bright illumination causes all colors to tend somewhat towards yellow in their hues. Helmholtz, Bezold, Rutherford, and others have made similar observations on the pure colors of the prismatic spectrum, and have found that even *they* undergo changes analogous to those just indicated. The violet of the spectrum is easily affected: when it is feeble (that is, dark), it approaches purple in its hue; as it is made stronger, the color changes to blue, and finally to a whitish grey with a faint tint of violet-blue. The changes with the

ultramarine blue of the spectrum follow the same order, passing first into sky-blue, then into whitish blue, and finally into white. Green as it is made brighter passes into yellowish-green, then into whitish-yellow; for actual conversion into white it is necessary that the illumination should be dazzling. Red resists these changes more than the other colors; but if it be made quite bright, it passes into orange and then into bright yellow. It is remarkable that these changes take place with the pure colors of the spectrum.*

We pass now to the changes which occur when the intensity of colored light is made very feeble. Von Bezold has made some interesting observations of this character on the colors of the spectrum. With a very bright prismatic spectrum he was able to see a pure yellow near D, and a whitish blue near F, the other colors being in their usual positions. When the illumination was only moderately bright, the yellow space diminished and became very narrow; the ultramarine blue vanished and was replaced by violet. With less illumination, the orange-yellow space assumed the color of red lead, and the yellow vanished, being replaced by a greenish tint; the cyan blue was replaced by green, the blue and ultramarine-blue by violet. The spectrum at this stage presented scarcely more than

*Abney has proved that if the spectrum is a perfectly pure one, the red below $B\frac{1}{2}C$ and the violet above $G\frac{3}{4}H$ do not undergo these changes.

three colors, red, green, and violet. With a still lower illumination, the violet vanished, the red became red-brown, and the green was visible as a pale-green tint; then the red-brown disappeared, the green still remaining, though very feeble. With still less light, even this suggestion of color vanished, and the light appeared simple grey.

The tendency of these experiments is evidently just the reverse of what was observed when the illumination was very bright. In that case the colored light as it increased in brightness gradually set all three sets of nerves into action, and the result was white or yellowish-white; but here the action of the colored light as it grows feebler is more and more confined to a single set of nerves. From this it results that those color-sensations which are due to the joint action of two sets of nerves speedily diminish when the color is darkened, and are replaced by the primary sensations, red, green, or violet. The sensation of orange is produced by those light-waves in the spectrum which have a length such as to enable them to stimulate the red nerves strongly and the green nerves to a lesser degree; hence, when orange colored light is made very weak, it fails to act on the green nerves while still feebly stimulating the red, and consequently the sensation of orange passes over into red. For similar reasons the sensations of yellow and

greenish-yellow pass into green, as do also those of greenish-blue and cyan-blue; in the same way the sensations of blue, ultramarine-blue, and violet-blue pass into violet. It is quite evident that these changes furnish another argument in favor of Young's theory of color, and also tend to approve the selection of red, green and violet as the fundamental color sensations.

Changes in luminosity produce still other effects which are quite remarkable. If we arrange by ordinary daylight sheets of red and blue paper, which have as far as we can judge about the same degree of luminosity, and then carry them into a darkened room, we shall be surprised to find that the blue papers appear brighter than the red. Indeed, the room may be so nearly darkened as to cause the red paper to appear black, while the blue still plainly retains its color. By similar experiments it can be proved that red, yellow and orange-colored surfaces are relatively more luminous when exposed to a bright light than blue and violet surfaces; the latter, on the other hand, have the advantage when the illumination is feeble.

GRADATIONS OF COLOR IN NATURE,

By Professor Rood.

ONE of the most important characteristics of color in nature is the endless, almost infinite gradations which always accompany it. It is impossible to escape from the delicate changes which the color of all natural objects undergoes, owing to the way the light strikes them, without taking all the precautions necessary for an experiment in a physical laboratory. Even if the surface employed be white and flat, still some portions of it are sure to be more highly illuminated than others, and hence to appear a little more yellowish or less greyish; and, besides this source of change, it is receiving colored light from all colored objects near it, and reflecting it variously from its different portions. If a painter represents a sheet of paper in a picture by a uniform white or grey patch, it will seem quite wrong, and can not be made to look right till it is covered by delicate gradations of light and shade and color. We are in the habit of thinking of a sheet of paper as being quite uniform in tint, and yet instantly reject as insufficient

such a representation of it. In this matter our unconscious education is enormously in advance of our conscious; our memory of sensations is immense, our recollections of the causes that produce them utterly insignificant; and we do not remember the causes mainly because we never knew them.

These ever present gentle changes of color in all natural objects give to the mind a sense of the richness and vastness of the resources of Nature; there is always something more to see, some new evanescent series of delicate tints to trace; and even where there is no conscious study of color, it still produces its effect on the mind of the beholder, giving him a sense of the fullness of Nature, and a dim perception of the infinite series of gentle changes by which she constantly varies the aspects of the commonest objects. This orderly succession of tints gently blending into one another, is one of the greatest sources of beauty that we are acquainted with, and the best artists constantly strive to introduce more and more of this element into their works, relying for their triumphs far more on gradations than on contrasts.

Ruskin, speaking of gradation of color, says: "You will find in practice that brilliancy of hue and vigor of light, and even the aspect of transparency in shade, are essentially dependent on this

character alone: hardness, coldness and opacity resulting far more from *equality* of color than from nature of color." In another place the same author, in giving advice to a beginner, says: "And it does not matter how small the touch of color may be, though not larger than the smallest pin's head, if one part of it is not darker than the rest, it is a bad touch; for it is not merely because the natural fact is so that your colors should be gradated; the preciousness and pleasantness of color depends more on this than on any other of its qualities, for gradation is to color just what curvature is to lines, both being felt to be beautiful by the pure instinct of every human mind, and both, considered as types, expressing the law of gradual change and progress in the human soul itself. What the difference is in mere beauty between a gradated and ungradated color may be seen easily by laying an even tint of rose-color on paper and putting a rose-leaf beside it. The victorious beauty of the rose as compared with other flowers depends wholly on the delicacy and quantity of its color-gradations, all other flowers being either less rich in gradation, not having as many folds of leaf, or less tender, being patched and veined instead of being flushed."

THE CHARM OF COLOR,

By Professor Rood.

THE power to perceive color is one of the most indispensable endowments of our race; deprived of its possession, we should be able not only to exist, but even to attain a high state of intellectual and æsthetic cultivation. Eyes gifted merely with a sense for light and shade would answer quite well for most practical purposes, and they would still reveal to us in the material universe an amount of beauty far transcending our capacity for reception. "But over and above this we have received yet one more gift, something not quite necessary, a benediction as it were, in our sense for and enjoyment of color." It is hardly fair to say that without this gift nature would have appeared to us cold and bare; still, we should have lost the enjoyment of the vast variety of pleasant and refined sensations produced by color as such and by color combinations; the magical drapery which is thus cast over the visible world would have given place merely to the simpler and more logical gradations of light and shade. The love of colour is a part of our constitution as much as

the love of music ; it developes itself early in childhood and we see it exhibited by savage as well as cultivated races. We find the love of color manifesting and making itself felt in the strangest places ; even the most profound mathematicians are never weary of studying the colors of polarized light, and there can be no doubt that the attractive power of color has contributed to swell the mathematical literature of this subject. The solar spectrum with its gorgeous tints was for many years before the discoveries of Kirchhoff and Bunsen a favorite, almost a beloved subject of study with physicists ; the great reward of this devotion was withheld for nearly half a century ; divested of its color-charm, attracting less study, the spectrum might still have remained an enigma for another hundred years.

Color is less important than form, but casts over it a peculiar charm. If form is wrongly seen or falsely represented, we feel as though "the foundations were shaken" ; if the color is bad, we are simply disgusted. Color does not assist in developing form ; it ornaments and at the same time slightly disguises it ; we are content to miss some of the modelling of a beautiful face for the sake of the color-gradations which adorn and enliven it.

APPENDIX.

REPORT OF THE PHOTOGRAPHIC SOCIETY OF PHILADELPHIA.

THE following is the report of a special committee appointed by the Board of Directors of the Photographic Society of Philadelphia, September 1st, 1892. It was approved by the Board December 1st, and adopted unanimously by the Society December 14th :

PHILADELPHIA, 23rd, November, 1892.

To the Board of Directors of the Photographic Society of Philadelphia :

Your Committee appointed "to take into consideration the advisability of some form of recognition by the Society of Mr. Ives' work in connection with Composite Heliochromy," have given the subject very full and careful consideration, and they respectfully report that in their opinion the work of Frederic E. Ives is worthy of the highest form of recognition which the Photographic Society of Philadelphia can give.

Before entering into any description of what Mr. Ives has done, your committee deem it wise they should in their report clear the ground of any misapprehensions which might arise from the terms used in dealing with the subject. Mr. Ives' process is not the kind of color photography for which the world has been looking, and may never find, nor is it "photography in natural colors" in the sense in which those terms are commonly understood. In a technical and scientific sense "natural colors" are those which are produced in any substance by the direct effect of light itself, acting in accordance with the laws of nature. Mr. Ives has, nevertheless, realized one solution of the problem, and the colors which are reproduced from nature by his process are as correct as are ordinary photographs in rendering in monochrome the effects of light and shade. In other words, "Composite Heliochromy," being a purely photographic process, is subject to the same limitations which circumscribe photography. When a process of photography is perfected which will avoid the defect of flattening the high lights when a sufficient exposure is given to bring out detail in the shadows, and the defect of undue increase of contrast in the middle shades, then the results of Composite Heliochromy will be perfected in like degree.

Mr. Ives' system of color photography, which he has named "Composite Heliochromy," consists—

1. In the production of a triple photograph or chromogram, one image of which represents by its light and shade the effect of light from the object upon the fundamental red sensation, another the effect upon the fundamental green sensation, another the effect upon the fundamental blue-violet sensation, in accordance with the Young-Helmholtz theory of color vision, and

the actual measurements by Maxwell and Abney of the relative power of different spectrum rays to excite the respective fundamental color sensations.

2. The optical superposition of the three images of the chromogram, either by means of a triple optical lantern, or in a table instrument known as the Photochromoscope, in which the image of the red sensation is seen by red light, the image of the green sensation by green light, and the image of the blue-violet sensation by blue-violet light, but with the three blended together to form a single image, which reproduces the light and shade and colors of the objects photographed.

The triple photograph is made by a single exposure, on a single sensitive plate, and from a single point of view, by means of a special camera of Mr. Ives' invention, in which the incident light is divided by the partial reflection and partial transmission of light by transparent mirrors, ingeniously arranged to secure the projection of the three images on a single plane, with identical perspective. The sensitive plates employed are sensitive to all the visible spectrum rays, which are made to act in the production of the three images in proportion to their power to excite the respective fundamental color sensations. This result is accomplished by filtering the light which goes to each image through a selective color screen, which has been adjusted by experiment in photographing the spectrum itself, to secure in the spectrum photograph a density curve corresponding to the graphic curve of the same sensation in Maxwell and Abney's diagrams. The adjustment of such a camera can only be made by a scientfic expert, familiar with the laws of optics and the use of the photospectrograph and the photometer: but when the adjustment is once made

the successful operation of the process is brought within reach of any skilled amateur photographer, no more operations being necessary than for the production of an ordinary negative and lantern slide.

The Photochromoscope is a neat table instrument containing the same system of reflectors as the camera. By its use the chromogram is seen as a single picture, reproducing the natural colors as readily as a stereogram is seen in the stereoscope reproducing binocular vision.

The first suggestion of composite color photography was made, we believe, by Henry Collen, of England, in 1865, and improved upon by DuHauron and Cros, in France, in 1869 and after, but without recognition of certain principles of color vision, the application of which Mr. Ives holds to be essential to success. Mr. Ives has been charged with making claims that are unfair to DuHauron and Cros, but a careful examination of his publications upon this subject has satisfied your committee not only that he has stated the claims of his predecessors in this intricate and not generally understood field of research, fully, clearly, and fairly, but he has repeatedly given the references to the original publications of Collen, DuHauron, and Cros, in order that the accuracy of his statements might be readily verified, and has stated his own claims so clearly that if his predecessors had had the same ideas the facts could readily be proved. On the other hand, we have been struck by the fact that writers who have charged Mr. Ives with unfairness have themselves, either through ignorance or with intentional unfairness, failed either to describe his process or to state his claims, and have ignored altogether points of difference which Mr. Ives has insisted upon, for reasons which he has given, as being absolutely essential to success.

The following is a brief statement of Mr Ives' claims, which he has communicated to this committee :—

1. "A triple photograph, one image of which represents by its light and shade the effect of light from the object upon the fundamental red sensation, another the effect upon the fundamental green sensation, another the effect upon the fundamental blue-violet sensation. This claim dates from November 21st, 1888 (Journal of the Franklin Institute, January 1889), previous to which date no one else had made photographs answering to this description, or recognized the principles involved. Such photographs are obtained by a method of precision, in accordance with actual measurements of the effect of different spectrum rays upon the separate fundamental color-sensations. (United States Patent No. 432, 530, July 22nd, 1890).

As bearing upon the above claim, Mr. Ives points out that making photographs "through red, green, and violet glasses, or "by red, green, and violet rays," as finally recommended by DuHauron and Cros, is either positively and fatally wrong, or else the names of colors are used in such an indefinite sense that the statements have only a vague meaning, indicating no definite principle or system of color selection, and nobody working with such vague ideas ever accomplished anything of value.

2. "A camera producing the triple photograph on a single sensitive plate, by a single exposure, from one point of view." (United States Patent No 475,084, May 17th. 1892.)

It is a well-known fact that many unsuccessful attempts were made to devise such a camera, and that several provisional patents were taken out for ideas that failed to accomplish the desired result.

3. "The Photochromoscope, the only successful device for optically recombining the three images of the chromogram to form one image on the retina of the eye, reproducing the colors." (United States Patent No. 475,084, May 17th, 1892.)

Mr. Ives also points out that it is important to recognize that this system makes photographs by the action of all visible spectrum rays, but shows them by means of three kinds of spectrum rays only, and that nobody else saw the necessity for such a procedure, although no other is possible in accordance with the modern theory of color vision.

It is further claimed that the above mentioned improvements have—

1. Solved the problem of reproducing the natural colors by photography.

2. Simplified the procedure so much as to make it possible for any good photographic operator to make the photographs, when supplied with the special camera, even if he have no knowledge whatever of color science.

It appears to this committee that Mr. Ives' claims are sustained, not only by argument and references, but also by his exhibition of results, which may fairly be said to be wonderful improvements upon anything obtained by his predecessors. In fact, while the results obtained by DuHauron and others are described as crude and unsatisfactory, Mr. Ives shows, by his process in the Photochromoscope, reproductions so perfect that it is sometimes difficult to realise that one is not looking at a reflection of the object itself, instead of a photograph.

Mr. Ives has pointed out that the results have one defect, which exists in all photographs, as has been already indicated, although it is less noticeable in the

absence of color. This defect, as has been said, is an increase of contrast in the middle shades of the picture at the expense of both ends of the scale. Ordinary photographs are relatively too flat in the high-lights, and wanting in detail in deep shadows; and in the color photographs the colors are apt to appear somewhat bleached out in the lighter shades and too dull in the shadows. This defect is not noticeable in reproductions of some subjects, but quickly attracts attention in others. For instance, a bright sky will in some instances not be as blue in the reproduction as its own reflection in a body of water, because the greater light intensity of the sky itself produces the effect of bleaching out by over-exposure. Since this is the result of a defect inherent in all photographic processes, it should not be charged against the system of color selection.

It is also stated that delicate shades of color will go wrong in the high lights when the sensitive plates are unevenly coated, especially if the coating be thin. The remedy is obvious, and lies with the platemakers.

In conclusion your committee submit that, in view of the great importance of the results achieved by Mr. Ives, the Society of which he has long been an active member should use its influence to secure to him just recognition for his scientific labors. To that end we recommend the adoption of the following :—

Resolved, That the Board of Directiors recommend to the Society the adoption of the following preamble and resolutions :—

WHEREAS, Frederic E. Ives, of Philadelphia, has, by the application of his new principle in composite heliochromy (dating November 21st, 1888), made a

practical solution of the problem of recording and reproducing by photographic means the colors of nature; and

WHEREAS, Mr. Ives has, not only in this connection but in many other ways, notably in the field of photo-mechanical printing processes, orthocromatic photography, and optical projection, made distinguished contributions to the progress of the art and science of photography; and

WHEREAS, The Photographic Society of Philadelphia is incorporated for the special object of increasing and diffusing "the knowledge of those natural laws which relate to the action of light, and particularly to promote improvements in the art of photography;" it is therefore

Resolved, That as a special recognition of the eminent scientific labors of Frederic E. Ives, a gold medal is hereby awarded to him by the Photographic Society of Philadelphia.

All of which is respectfully submitted.

GEO. M. TAYLOR,
Chairman,
GEORGE VAUX, JR.,
EDMUND STIRLING,
JNO. G. BULLOCK,
C. R. PANCOAST,
Committee.

REPORT OF THE FRANKLIN INSTITUTE.

THE following is the report of the Committee on Science and Arts of the Franklin Institute, to which the subject of Mr. Ives' Photochromoscope system of color photography was referred for consideration by a vote of the members at a stated meeting of the Institute.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, September 6th, 1893.

COMMITTEE ON SCIENCE AND ARTS.
Report, No. 1689.

Subject:—"*Ives' System of Colour Photography.*"

The Committee on Science and Arts, constituted by the *Franklin Institute*, of the State of Pennsylvania, for the promotion of the Mechanic Arts, to which was referred for examination, "Frederic Ives' System of Colour Photography."

REPORT:—

That in order to satisfy themselves as to what had been accomplished by other workers in the line of Colour Photography, they corresponded with the following named gentlemen, viz:—Prof. Lippman, Paris; M. Leon Vidal, Paris; Dr. H. W. Vogel, Berlin; and Dr. Eder, Vienna.

They received replies from M. Leon Vidal and Dr. Vogel. The former disclaimed any originality in heliochromy so far as he was concerned, and stated that he had simply experimented with polychromic projections on the lines laid down by others.

Dr. Vogel submitted, through Mr. Kurtz of New

York, specimen prints in colour, printed on the power press in three impressions to represent the colours of nature; two subjects from nature, and one taken from a sample of carpet. These prints seem to possess considerable merit, although not having the originals before us for comparison, we are unable to judge how correctly their colours are reproduced.

We conclude from the examination of these specimens and from statements of Dr. Vogel in a letter submitted to us, that Dr. Vogel and Mr. Ives, although both workers in the line of colour photography, yet are operating in different directions, and we are of opinion that Dr. Vogel's claims do not interfere with those of Mr. Ives, and need not therefore be further considered.

The committee, to satisfy themselves of the claims made by Mr. Ives, to reproduce the colours of nature of any object by means of his special camera and Photochromoscope, provided a bouquet of flowers, which was photographed in their presence by Mr. Ives with his special camera, in which one lens only was used to make a triple negative on a single plate at one exposure.

The Committee having seen the negative developed, and a triple positive made therefrom in the usual manner, the latter was placed in the Photochromoscope and viewed by your committee in comparison with the original bouquet. It was their unanimous opinion that Mr. Ives' claims were fully borne out in the demonstration there witnessed.

The bouquet furnished, consisted of flowers specially selected by your committee, having the colours red, blue, yellow and green of both strong and delicate tints; furnishing a very severe test of his process.

Other examples were submitted by Mr. Ives and examined critically by the committee, the original objects in many cases being placed beside the Photochromoscope for comparison, and though different in both substance and colour from the bouquet of flowers, they were rendered with great fidelity.

The Committee in describing the demonstration made by Mr. Ives, as above set forth, to avoid any misconception of their report, desire it to be distinctly understood, that they do not wish to convey the idea that Mr. Ives either reproduces the colours in the camera direct, or in the nature of prints, as aimed at by Albert. Vogel, and others, but by aid of his special camera having one lens, producing three images equal in form and perspective on a single sensitive plate by means of a system of reflecting and refracting mirrors, which in connection with suitable colour screens, yields a negative giving the correct record *in monochrome* of the original colours photographed. From this triple negative a triple positive is then made which when placed in an instrument, invented by Mr. Ives, and known as the Photochromoscope, a similar device to the camera, the object originally photographed is shown in its true form and colours.

Herewith, we present the claims as made in brief by Mr. Ives :—

"1. A triple photograph, one image of which represents by its light and shade the effect of light from the object upon the fundamental red sensation; another the effect upon the fundamental green sensation; another the effect upon the fundamental blue-violet sensation. This claim dates from November 21st, 1888, (Journal of the Franklin Institute, January, 1889), previous to which no one else had

made photographs answering to that description or recognized the principle involved. Such photographs are obtained by a method of precision, in accordance with actual measurements of the relative power of different spectrum rays to excite the separate fundamental color sensations.

"N.B.—To make photographs "through red, green and violet glasses" or by "red, green and violet rays" is either positively and fatally wrong, or else the names of colours are used in such an indefinite sense that the statements have only a vague meaning. Nobody working with such vague ideas ever did or ever would accomplish anything of value

"2. A camera producing the triple photograph on a single sensitive plate, by a single exposure, from one point of view. Although many tried, no one else succeeded in devising such a camera.

"Without such a camera, the procedure is too complicated and difficult to be carried out successfully by any but scientific experts.

"3. The photochromoscope; the only successful device for optically re-combining the three images of the chromogram to form one image on the retina of the eye, reproducing the colours.

"It is also important to recognize the fact that this system produces photographs by the action of all visible spectrum rays, but shows them by means of three kinds of spectrum rays only; and that no one else saw the necessity for such a procedure, although no other is possible in accordance with the modern theory of colour vision.

"It is further claimed that the above named improvements have :—

"*First,* solved the problem of reproducing the natural colours by photography.

"*Second,* simplified the procedure so much as to make it possible for any good photographic operator to make the photographs when supplied with the special camera, even if he have no knowledge whatever of colour science."

The Committee having carefully gone over the claims of Mr. Ives and his predecessors, and so far as able examined into their results, can come but to this conclusion: That Mr. Ives, by his original investigations and special construction of Camera and Photochromoscope for recording and reproducing colour, as set forth in United States Patent Specifications, No. 432, 530, July 22nd, 1890; and No. 475,084, May 17th, 1892; has offered a practical solution of the problem of reproducing by means of photography the colours of nature; and therefore award to Mr. Frederic E. Ives the Elliot Cresson Gold Medal, in recognition thereof.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 3rd, 1893.

H. R. HEYL, *Chairman.*
WM. H. WAHL, *Secretary.*

SCIENTIFIC RECOGNITION IN ENGLAND.

THE projection on the screen of Mr. Ives' color-photographs was first publicly made in Philadelphia, but the Photochromoscope, having been just completed before his visit to England in 1892, was first exhibited in London, before the Royal Society, at the conversazione in May, by invitation of the President, Lord Kelvin. It was next shown at the Royal Institution, in connection with two afternoon lectures by Mr. Ives on the subject of "Photography in the Colors of Nature," and soon after at the Society of Arts, where Mr. Ives read a paper on "Composite Heliochromy," for which he was awarded the Society's Medal. It was also shown at the Camera Club. It was again exhibited at the Society of Arts, the Royal Institution and the Camera Club in 1893, and on the occasion of Mr. Ives' second lecture at the Society of Arts, Captain Abney, the Chairman, spoke in the highest terms of the scientific character of the method, the ingenuity of the special devices employed, and the beauty of the results.

ADVERTISEMENT.

IN due time, the Photochromoscope will be obtainable through the usual channels for optical and photographic apparatus. Mr. Ives has not been anxious to hasten such a result, for, in such leisure as he has found consistent with work in other directions, he has been able to make improvements in his apparatus and methods which will be all to the greater advantage of those who may desire to possess the instrument when it is ready for sale. Besides, by deliberate rather than by immediate action, Mr. Ives' claims to originality and the validity of his patents become the more incontrovertibly established.

When the Photochromoscope has been adopted and approved by the Public, it is intended to supply the color-camera to all who may desire to make their own chromograms, and also the special apparatus for screen projections.

For further information apply to either of the following:

Mr. F. E. IVES, 2750, North 11th Street, Philadelphia.
Mr. WM. H. WARD, Chislehurst, Kent.
Mr. HORACE WALLICH, 23a, Griesgasse, Vienna.